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COMBINING ABILITY ANALYSIS FOR QUANTITATIVE TRAITS IN RED SWEET PEPPER (*CAPSICUM ANNUUM* L. VAR. *GROSSUM* SENDT.) GROWN UNDER PROTECTED CONDITION

CHERRY NALWA* AND MANISH KUMAR

Department of Seed Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, Solan (HP) 173 230, India

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Abstract

Six red sweet pepper genotypes *viz.*, RSPUHF-1, RSPUHF-2, RSPUHF-3, RSPUHF-4, RSPUHF-5 and RSPUHF-7 and their crosses using half-diallel excluding reciprocals were evaluated for combining ability to obtain desired hybrids. Analysis of variance for combining ability revealed that variances due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for all the characters indicating the importance of additive and non-additive gene effects. RSPUHF-3 (–1.42* and –1.5*) and RSPUHF-7 (–1.25* and –1.54*) were found as reliable combiners for earliness and maturity. Whereas, the parents RSPUHF-1 (0.53*, 0.78*, –0.5, 0.12*, 0.25*), RSPUHF-2 (1.49*, 2.19*, 6.41*, 0.63*, 2.21*) and RSPUHF-4 (0.69*, 0.9*, 9.92*, 0.47*, 1.28*) were good general combiners for fruit set per cent, number of fruits per plant, fruit weight, fruit yield per plant and fruit yield per m^2. Amongst, the crosses, RSPUHF-3 × RSPUHF-2 (0.95*), RSPUHF-4 × RSPUHF-2 (0.77*) and RSPUHF-5 × RSPUHF-2 (0.86*) were found to be the best specific combinations for increased fruit yield and component characters. Further, on the basis of *per se* performance it may be identified for release after multi location testing the above hybrids have been found to be the most promising for exploitation of heterosis.

Sweet pepper occupies a pride of place among vegetables in Indian cuisine, because of its delicate taste, colour and pleasant flavour coupled with rich ascorbic acid, vitamin-A, minerals and their attractive red color which is due to several carotenoid pigments (Deepa *et al.* 2006). It has also got a good potential as a greenhouse crop since quality of fruits is superior as compared to open field cultivation which fetches higher prices in the market (Farooq *et al*. 2015). The requirement of quality rich nutritious sweet pepper fruits available in different color variants is further increasing manifold due to consumer's preference for healthy food and meet the growing demand for which development of new cultivars for greenhouse growing would be one of the strongest options. Mostly in India, red, yellow and orange color peppers are grown commercially. But the availability of seed is always a concern, since mostly these varieties are of foreign origin. Hence, there is a growing need to develop varieties/hybrids indigenously and therefore, an attempt has been made to test the combining ability of available lines and their crosses in the present studies.

Development of F_1s is very much helpful to adopt variety/hybrid for successful commercial cultivation of sweet pepper. For the development of F_1s parents are selected on the basis of their both general and specific combining ability (Ahmed *et al.* 2009). These estimates are helpful in screening the parental lines for using them in developing desired hybrids and to identify suitable cross combinations from different parents for commercial exploitation as a variety.

Six diverse red sweet pepper lines *viz.*, RSPUHF-1, RSPUHF-2, RPUHF-3, RSPUHF-4, RSPUHF-5 and RSPUHF-7 and their 15 cross combinations were considered for this study. The crossing was attempted in half-diallel fashion excluding reciprocals during April, 2017 under

*Author for correspondence: <cherrynalwa.123.cn@gmail.com>.

plastic greenhouse. All the parents, 15 F_1 cross combinations and the standard check Bomby were further planted during Kharif, 2018 for their evaluation and generation of data with three replications using RBD design at the experimental farm of Dr. Y.S. Parmar, University of Horticulture & Forestry, Nauni, Solan (HP), India. Each plot consisted of size 2.0 m × 1.0 m with spacing of 70 cm × 40 cm. The observations were recorded on ten randomly selected plants for days to first flowering, fruit set per cent, number of fruits per plant, fruit weight, fruit yield kg per plant, fruit yield kg per m^2 and days to first ripe fruit harvesting. The data were subjected to analysis for general and specific combining ability following Griffing (1956).

The analysis of variance for combining ability (Tables 1 - 2) revealed that mean sum of squares was found to be significant for all the characters. For days to first flowering and days to first ripe fruit harvesting, RSPUHF-3 and RSPUHF-7 showed significant and negative GCA values. RSPUHF-1, RSPUHF-2 and RSPUHF-4 exhibited highly significant GCA values and thus considered as good general combiners for fruit set per cent and number of fruits per plant. General combining ability for fruit weight, fruit yield per plant and fruit yield kg per m^2 revealed significant and positive effects by lines RSPUHF-2 and RSPUHF-4 showing superiority of GCA. It was observed that the use of parents RSPUHF-2 and RSPUHF-4 in future breeding programme which is useful for important fruit quality and yield components. These results pointed out that selection of parents for hybridization programme based on *per se* performance were reliable and such parents turned out to be good combiners. The results are in conformity with Pandey *et al.* (2002), Gomide *et al.* (2003), Johri *et al.* (2004) and Sood and Kumar (2010).

Table 1. Estimates of general combining ability of parents for different traits in sweet pepper.

Parents/ crosses	Days to first flowering	Fruit set (%)	Number of fruits/ plant	Fruit wt. (g)	Fruit yield (kg/plant)	Fruit yield (kg/m^2)	Days to first ripe fruit harvesting
RSPUHF-5	0.58*	–0.097*	–1.68*	0.75	–0.3*	–0.5*	0.33*
RSPUHF-7	–1.25*	–0.18	0.07	–8.91*	–0.26*	–0.97*	–1.54*
RSPUHF-3	–1.42*	–2.43*	–2.26*	–7.67*	–0.67*	–2.25*	–1.5*
RSPUHF-4	1.42*	0.69*	0.9*	9.92*	0.47*	1.28*	1.54*
RSPUHF-1	0.50*	0.53*	0.78*	–0.5	0.12*	0.25*	0.79*
RSPUHF-2	0.17	1.49*	2.19*	6.41*	0.63*	2.21*	0.38*
SE (gi)	0.16	0.13	0.22	0.72	0.06	0.22	0.14
SE (gi-gj)	0.25	0.2	0.34	1.11	0.09	0.34	0.22
CD (gi)	0.32	0.26	0.44	1.45	0.12	0.44	0.28
CD (gi-gj)	0.50	0.40	0.68	2.23	0.18	0.68	0.44

Significant at 5% level of significance.

Significant and negative SCA values were shown by seven hybrids *viz.*, RSPUHF-7 × RSPUHF-2, RSPUHF-7 × RSPUHF-1, RSPUHF-7 × RSPUHF-4, RSPUHF-5 × RSPUHF-1, RSPUHF-7 × RSPUHF-3, RSPUHF-5 × RSPUHF-7 and RSPUHF-3 × RSPUHF-2 for days to first flowering and days to first ripe fruit harvesting. Amongst the 15 hybrids, six crosses RSPUHF-4 × RSPUHF-2, RSPUHF-3 × RSPUHF-2, RSPUHF-5 × RSPUHF-4, RSPUHF-5 × RSPUHF-2, RSPUHF-5 × RSPUHF-1 and RSPUHF-1 × RSPUHF-2 were good specific combiners for fruit set per cent. For number of fruits per plant the crosses RSPUHF-5 × RSPUHF-2, RSPUHF-5 × RSPUHF-4, RSPUHF-4 × RSPUHF-2, RSUHF-3 × RSPUHF-2, RSPUHF-1 × RSPUHF-2, RSPUHF-5 × RSPUHF-3 and RSPUHF-5 × RSPUHF-1 were found to be good specific combiners (Table 2). The best SCA effect for fruit weight was exhibited by combinations

RSPUHF-3 × RSPUHF-2, RSPUHF-5 × RSPUHF-3, RSPUHF-5 × RSPUHF-2, RSPUHF-3 × RSPUHF-1, RSPUHF-3 × RSPUHF-4, RSPUHF-4 × RSPUHF-2 and RSPUHF-1 × RSPUHF-2. Crosses involving RSPUHF-5 × RSPUHF-4, RSPUHF-3 × RSPUHF-2, RSPUHF-5 × RSPUHF-2, RSPUHF-4 × RPUHF-2, RSPUHF-5 × RSPUHF-3, RSPUHF-1 × RSPHF-2 and RSPUHF-3 × RSPUHF-4 had maximum SCA effects for fruit yield per plant. Whereas, for fruit yield kg per m^2, four crosses RSPUHF-5 × RSPUHF-3, RSPUHF-5 × RSPUHF-2, RSPUHF-4 × RSPUHF-2 and RSPUHF-1 × RSPUHF-2 exhibited highly significant and positive SCA effects. Significant and positive SCA effects for fruit set, number of fruits per plant, fruit weight and fruit yield have also been reported by Maulf *et al.* (1997), Mulge and Anand (1997), Gomide *et al.* (2003), Geleta and Labuschagne (2006), Rekha *et al.* (2007) and Hasanuzzaman *et al.* (2012).

Table 2. Estimates of specific combining ability of crosses for different traits in sweet pepper.

Parents/ crosses	Days to first flowering	Fruit set (%)	Number of fruits/ plant	Fruit weight (g)	Fruit yield (kg/plant)	Fruit yield (kg/m^2)	Days to first ripe fruit harvesting
RSPUHF-5 × RSPUHF-7	−1.25*	−0.18	0.07	−8.91*	−0.26	−0.99	−1.54*
RSPUHF-5 × RSPUHF-3	6.1*	0.02	2.18*	11.53*	0.74*	1.83*	6.52*
RSPUHF-5 × RSPUHF-4	−0.41	2.57*	2.68*	−9.08*	1.97*	0.55	−1.52*
RSPUHF-5 × RSPUHF-1	−3.16*	2.07*	1.14*	−3.68*	0.07	0.58	−3.77*
RSPUHF-5 × RSPUHF-2	0.52	2.11*	2.72*	11.1*	0.86*	3.74*	0.98*
RSPUHF-7 × RSPUHF-3	−1.42*	−2.43*	−2.26*	−7.67*	−0.67*	−2.25*	−1.5*
RSPUHF-7 × RSPUHF-4	−3.58*	−4.19*	−3.66*	−17.39*	−1.19*	−3.54*	−3.9*
RSPUHF-7 × RSPUHF-1	−3.99*	−3.02*	−2.86*	−7.75*	−0.75*	−2.35*	−6.48*
RSPUHF-7 × RSPUHF-2	−4.32*	−5.64*	−5.29*	−15.43*	−1.45*	−4.64*	−4.73*
RSPUHF-3 × RSPUHF-4	1.42*	0.69	0.9	9.92*	0.47*	1.28	1.54*
RSPUHF-3 × RSPUHF-1	2.85*	−6.48*	−4.03*	10.06*	−0.57*	-0.51	3.48*
RSPUHF-3 × RSPUHF-2	−1.16*	3.57*	2.22*	13.51*	0.95*	3.5	−0.44
RSPUHF-4 × RSPUHF-1	0.5	0.53	0.78	−0.5	0.12	0.25	0.79*
RSPUHF-4 × RSPUHF-2	0.76	5.07*	2.68*	6.69*	0.77*	2.14*	1.31*
RSPUHF-1 × RSPUHF-2	0.17	1.49*	2.19*	6.41*	0.63*	2.21*	0.38
S.E(ij)	0.44	0.36	0.6	1.97	0.15	0.6	0.38
S.E. (sij-skl)	0.61	0.5	0.82	2.73	0.21	0.83	0.53
CD (sij)	0.88	0.72	1.21	3.96	0.30	1.21	0.76
CD (sij-skl)	1.23	1.01	1.65	5.49	0.42	1.67	1.07

Significant at 5% level of significance.

The estimates of components of variation revealed that both additive and non-additive gene effects were important for most of the characters (Table 3). However, the magnitude of non-additive components was more than additive components for most of the traits indicating preponderance of dominance effects in expression of these traits. The perusal of the data further indicates that estimates of $\sum^2$ s were higher in magnitude as compared to $\sum^2$ g for all the traits. The closer the predictability ratio to one, the greater the prediction of GCA alone, whereas a ratio with value less than one shows SCA action (Baker 1978). This ratio was found less than one for all the traits *viz.*, days to first flowering (0.07), fruit set (0.05), number of fruits per plant (0.14), fruit weight (0.20), fruit yield kg per plant (0.17) and fruit yield kg per m^2 (0.16). It further confirmed the predominant role of non-additive gene action in the expression of all the traits. Non-additive gene action has also been recorded by Sood and Kumar (2011) and Kordus (1991) in a set of pepper crosses for many traits. The preponderance of non-additive gene action clearly suggests exploitation of heterosis breeding for the improvement of these traits and presence of sufficient hybrid vigour in these cross-combinations. Three best performing parents being good general combiners and best hybrids being good specific combiners for different traits also corroborated with good *per se* performance as good (Table 4).

Table 3. Estimates of genetic components of variance for different traits in sweet pepper.

Character	$\sum^2$ gca	$\sum^2$ sca	$\sum^2$ g	$\sum^2$ s	$\sum^2$g/$\sum^2$s (variance ratio)	Predictability ratio (2 $\sum^2$g/2 $\sum^2$g+$\sum^2$s)
Days to first flowering	148.667	472.095	14.90	442.66	0.03	0.07
Fruit set per cent	214.056	920.548	24.36	900.77	0.03	0.05
Number of fruits/plant	340.556	535.095	35.78	480.746	0.07	0.14
Fruit weight (g)	6686.116	7510.650	761.49	6916.451	0.11	0.20
Fruit yield kg/plant	29.872	38.784	30.28	35.181	0.09	0.17
Fruit yield kg/m^2	309.057	415.700	31.68	360.108	0.09	0.16
Days to first ripe fruit harvesting	189.167	696.548	20.84	674.072	0.03	0.06

Table 4. Three best crosses showing significant SCA effects, *per se* performance and standard heterosis for different traits under study.

Characters	Crosses	Mean value	SCA effect	Standard heterosis
Days to first flowering (Number)	RSP UHF-7 × RSP UHF-2	47.00	–4.32*	–9.04*
	RSP UHF-7 × RSP UHF-1	47.67	–3.99*	–7.75*
	RSP UHF-5 × RSP UHF-1	48.67	–3.16*	–5.81*
Fruit set (%)	RSP UHF-4 × RSP UHF-2	92.67	5.07*	2.59*
	RSP UHF-3 × RSP UHF-2	91.33	3.57*	1.11*
	RSP UHF-4 × RSP UHF-1	90.33	0.53	0.00
Number of fruits/plant	RSP UHF-4 × RSP UHF-2	35.00	2.68*	11.71*
	RSP UHF-3 × RSP UHF-2	34.67	2.22*	10.65*
	RSP UHF-5 × RSP UHF-2	34.33	2.72*	9.59*
Fruit wt. (g)	RSP UHF-3 × RSP UHF-2	225.84	13.51*	8.84*
	RSP UHF-3 × RSP UHF-4	218.73	9.92*	5.41*
	RSP UHF-3 × RSP UHF-1	215.48	10.06*	3.85*
Fruit yield (kg/plant)	RSP UHF-3 × RSP UHF-2	7.84	0.95*	17.70*
	RSP UHF-4 × RSP UHF-2	7.32	0.77*	9.85*
	RSP UHF-5 × RSP UHF-2	7.03	0.86*	5.51
Fruit yield (kg/m^2)	RSP UHF-3 × RSP UHF-2	19.60	3.5	21.19*
	RSP UHF-5 × RSP UHF-2	17.57	3.74*	8.65*
	RSP UHF-4 × RSP UHF-2	17.21	2.14*	6.46

It is revealed that the parents RSPUHF-2 and RSPUHF-4 were good general combiners for most of the traits which could be used in future breeding programme of sweet pepper as identified as trait specific varieties. The cross combinations with high degree of SCA effects involving both the parents having good GCA effects would be ideal for deriving desirable genotypes. The combinations RSPUHF-3, RSPUHF-2, RSPUHF-4 × RSPUHF-2 and RSPUHF-5 × RSPUHF-2 were found to be superior for all the traits in this regard and may be exploited commercially as potential F_1 varieties.

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